Industrial and Innovation Policy in the face of the Covid-19 Health Crisis: The case of South Africa's National Ventilator Project

A Research Report presented for:

A Degree of Masters of Commerce in Applied Development Economics

School of Economics and Finance

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Date: 7 Feb 2022

Abstract

The Covid-19 pandemic disrupted supply chains across the globe and production for many critical and essential goods was brought to a standstill. One of the essential goods that South Africa could not easily access was the medical equipment needed in the time of a health crisis. The pandemic put into sharp focus the challenges associated with global chains and the shortage of ventilators signaled that developing country's needed to prioritize self-sufficiency in medical equipment to avoid critical shortages in the future. The importance of knowledge transfer from resource-based to manufacturing industries has been widely studied in the South African context. This research extends the study of knowledge transfer by looking into the importance of knowledge transfer from other manufacturing sectors towards the knowledge and technological capability in the production ventilators. A case study of the National Ventilator Project (NVP) is undertaken by a method of semi-structured interview with individuals from companies that are involved in the project including public and private enterprises and bodies such as the National Association of Automotive Component and Allied Manufacturers, the South African Radio Astronomy Observatory and the Department of Trade, Industry and Competition. The study examined to what extent to which the NVP been successful in reconfiguring and retooling existing local manufacturing capabilities in other sectors towards ventilator production in an attempt to respond to the Covid-19 health crisis. The case study found that the project was successful and its success depended on a strong partnership between the state institutions, public organizations and the private sector. It was also found on the other hand, however, that there is not yet a long-term industrial policy strategy that aims to build continuous medical equipment production in South Africa. It is absolutely urgent that the government creates and clear and well-designed industrial policy that leverages on the learning that has been accrued during this crisis.

Keywords;

Industrial policy, Public-private partnership, Global Value Chain, Lateral Migration, National Ventilator Project

Acknowledgment

Foremost, I thank God for giving me the health, opportunity and support system to complete the Masters program and this research paper in time of global crisis.

I would like to express my sincere gratitude to my supervisor Dr Sibulele Nkunzi for his continuous support of my research, for his patience, motivation, enthusiasm, and immense knowledge. His guidance helped me in all the time of research and writing of this research report.

Last but not the least, I would like to thank my family: my mother Mintesnot Zewde; my husband Sitotaw Markos; my uncle Zelalem Fikadu, my sister Misegana Biru and my brother in-law Temesgen Yohanes, for giving me financial and emotional support.

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1. Introduction

COVID-19 pandemic is an "infectious disease which is caused by a novel coronavirus, it is a highly contagious disease which is believed to have begun in Wuhan, China at the end of December 2019 and now has spread across the globe" (Iyengar, Bahl, Vaishya &Vaish, 2020 p. 499). Thus, the year 2020 was one of the historical years of our time; due to the swift spread of the covid-19 global pandemic and its international socio-economic effect many have labelled it to be a period of war (Scott, 2020). Thus, the infectious nature of the pandemic forced many countries to have closed their international borders and implemented national lockdown as a measure of stopping the international spread of the virus (Park, Kim, & Roth 2020).

However, the impacts of closing borders have been heavy on international trade as many countries depend on the international supply chain especially in China (UNCTAD, 2020). Thus it caused trade between countries to be jeopardized (Park, Kim, & Roth 2020; OECD, 2020). The trade disruption with China affected many businesses that rely on the global value chain, for example, the Honda spoke person stated that "Honda Motor Co. will reduce vehicle output at two of its domestic plants in Saitama Prefecture for a week or so in March 2020 due to concerns about parts supply from China where a new coronavirus outbreak continues to disrupt economic activities" (UNCTAD, 2020 p.1). China is also the main source of other essential manufactured goods such as ventilators (Park, Kim, & Roth 2020). Thus countries that depend on imports for essential health equipment have experienced massive shortages during this crisis. The supply shortages experienced are similar to those shortage experiences exhibited by many countries that rely on imports during World War I and II (Carbonaro, 2020).

Consequently, most Heads of States such as the US and the French presidents have equated the crisis to a war (Carbonaro, 2020). Thus the measurements that are usually taken during war periods are underway during the covid-19 crisis (Carbonaro, 2020). For example, US President Donald Trump has implemented a policy called Defence Production Act (DPA) that was created in response to the Korean War and countries like South Africa, Japan and Ethiopia have implemented state of emergency measures to limit the spread of the virus (Carbonaro, 2020). The DPA was put in place to prioritise the local manufacturing of health

equipment's necessary such as Personal Protective Equipment (PPE) and ventilators to combat the covid-19 war (Carbonaro, 2020).

Aside from closing borders, many countries have implemented export bans on personal protective equipment (PPE) and ventilators to prioritise national safety (Carbonaro, 2020). As the New York governor puts it "ventilators are to this war are what bombs were to World War II" (Twitter, *@NYCMayor March 19, 2020*). Therefore creating means of PPE and ventilator production became an essential strategy. As a result, countries that face shortages of ventilators such as the United States and South Africa began reconfiguring their technology and production to meet domestic needs (Carbonaro, 2020; O'kane, 2020; SA news, 2020).

The rationale for ventilators is that as there was no particular treatment or vaccine available for this disease at the time of the outbreak, the critically ill patients suffering from COVID-19 needed respiratory support, due to the damaged lungs by the coronavirus leading to breathing difficulties. Ventilators are needed in such cases for supplying adequate oxygen (O2) into their lungs and also removing the carbon dioxide (CO2), as a lifesaving supportive measure (Iyengar, et al., 2020). Therefore the South African government initiated the National Ventilator Project (NVP) to meet these needs (SA news, 2020).

The Department of Trade, Industry and Competition (DTIC) proposed the NVP and mandated the South African Radio Astronomy Observatory (SARAO) to process the project (Wild, 2020). The project involves many engineering companies such as NACAAM, Rand York Casting, MRC Manufacturing and others (Wild, 2020). The aim is to begin manufacturing with non-invasive ventilators and upgrade to invasive ventilators (Wild, 2020).

Therefore this research paper aims to investigate the SKA/DTIC National Ventilator Project's Industrial Policy in the face of the Corona Virus and how the state is reorienting its capacity towards the development of equipment such as ventilators that are essential to meet the needs of the healthcare sector during this period. The research looks at the importance of state institutions, public organizations and the private sector reorienting their innovation and production efforts in times of crisis, looking into aspects of the design, development,

production and procurement of ventilators in the process as part of the range of needs that are emerging.

The research is structured in six sections. Following this chapter two of the research looks into the research methodology and lays out the research question, discusses the reason why a case study is chosen, proposes the hypothesis, gives an overview of how the interview is conducted and discusses the sample size. The third chapter looks into the litterateurs that are related to the topics of this research such as; lateral migration, public-private partnership, industrial policy and global value chain. Fourthly the findings from the interviews conducted are presented. The fifth section discusses the findings presents relating to the pieces of literature discussed followed by recommendations and shortcomings of the study. Finally, the last section concludes by summarising the discussion.

2. Research Methodology

2.1 Research Problem/Question

Covid-19 came in a moment where there were already some tensions in the global trading system and production networks. Even in the pre-2020 world, there had been growing protectionism and threats of trade wars in the major centres of manufacturing. What Covid-19 has done is to merely expose the fragility of global value chains. Fragility in the current context is used in the sense that if an important part of a value chain breaks down all downstream production is affected and entire nations face social and health perils. The vulnerabilities around the breakdown of ventilator value chains open up the industrial policy debate for how we should rethink the position and capacity of developing countries in the global industrial production of health-related equipment. So far, the coordinated attempts in South Africa between the state and manufacturers, both with a global and local footprint, signals the potential for developing countries to move away from relying on global supply chains for critical health equipment and reasserting themselves in a concentrated and contested knowledge and innovation space where big players protect and control their innovations and entire production networks to safeguard their profits.

Entire value chains in different sectors have faced dormancy and lost profits as industrial plants were shut down one after the other around the world. However, as value chains in

some of these areas faced major disruption, opportunities for manufactures to extend their production to equipment that is beyond their traditional manufacturing focus has been opened up. In other words, there is a lot of restructuring going on, not only at the macro-economic levels but down at plant levels as well. Thus this paper examines how the restructuring, reorienting and retooling being handled in South Africa through the lens of the NVP. The paper also looks at the contribution of knowledge transfer across sectors and the effect of public-private partnership in the project. Finally, the paper also looks at the effect of GVC disruption on the success of the NVP.

The main question that this research seeks to interrogate is: To what extent has the NVP been successful in reconfiguring and retooling local manufacturing capabilities in an attempt to respond to the Covid-19 Crisis?

The ancillary questions that support the main question are:

1. Is there significance in the partnership between the state institutions, public organizations and the private sector in reorienting their innovation and production efforts in the covid-19 crisis?
2. Does South Africa's manufacturing industry have what it takes i.e. actual capability, production capability and investment to produce ventilators if not is there capacity building (learning by doing)?
3. Is there a long-term innovative industrial policy (does it create future manufacturing possibilities) or is it only focused on combating the current medical equipment shortage?
4. Are there economies of scale for manufacturing ventilators? If not, how is it intended to be built and are there defined policies that are in place to promote economies of scale?

Hypotheses

The main hypothesis of this study is that the success of reorienting innovation and production efforts depends on strong a partnership between the state institutions, public organizations and the private sector. However, looking at public-private partnership without examining the contribution of the industrial policy involved in manufacturing is not complete. Thus, the

second hypothesis states that industrial and innovative policies are the pillars for successful manufacturing.

2.2 Research Method

The research is based on a case study on South Africa's national ventilator project. The case study method is chosen for the reason that the study was undertaken as a natural experiment in which the researchers have no control over the conditions of the process and its usefulness in investigating the process to gain sharp insight into cases and consequences (Thomas and Mohan, 2007). Furthermore, the natural experiment process of case studies is useful in the investigation of causality directly by looking in details at how the causal processes work within particular cases and how decisions are implemented as well as their results (Thomas et al., 2007).

The additional reasons for using the case study method are the research paper tries to address a specific phenomenal which is the NVP; how knowledge transfer contributes to the successful manufacturing of ventilators and because the paper tries to give in depth description of NVP (Thomas et al., 2007).

Therefore, a case study is found to fit our research as we are investigating the effectiveness and implementation process of industrial policy in the face of the coronavirus crisis. Furthermore, the case study method had helped us answer the "how" and "why" the state is reorienting its capacity toward the development of ventilators (Thomas et al., 2007).

The method of data collection for our case study was semi-structured interviews. The interview was undertaken to collect data. Companies that are involved in the project including public and private enterprises such as NAACAM and SARAO were interviewed. Qualitative variables were used when conducting the interviews.

Table 1: Questions used were adopted from Lorentzen (2006, p.13).

	Questions
Absorptive capacities or firm learning	• Nature of the technology and the resource base from which it originated

	• Nature of the new application and industry into which the technology migrated • Determinants of cumulative and present absorptive capacities (role of R&D spending, the share of R&D spending in turnover over time, advanced technical skills, manufacturing operations (if applicable) • Origin of the LM technology (blue sky, reverse engineering, licensing, involvement in global knowledge flows through scientific or other forms of cooperation, etc.) • Problems with any of the above: nature and cause • What is the capacity/scale of production and the capacity to upscale?
The role of foreign technology	• Did foreign technology inflows enhance incentives for innovation • diminish them because they obviated the need for indigenous generation of technology • mattered only in terms of content or also with respect to the transfer mode • Benefit from strong/weak IPRs?
Linkages and interactions	• What is the nature of the embeddedness of the innovating firm in a system of innovation (suppliers and customers, education and training

	providers, science institutes, sector associations, public authorities, standard bodies, etc.)? • Which interactions with other firms and with the knowledge infrastructure mattered, and why? • What have the coordination mechanisms between producers/manufacturers at both national and international levels entailed? • What relations have been forged between and more established companies in the automotive components space, for instance?
Industrial policy	• What sort of market failures did the innovating firm encounter, and how did it (or not) overcome them? • What was the role of industrial policy? • What successes/obstacles have there been in the area of intellectual property? • What has been the roles of the government (as a regulator, facilitator, financer and procurer)in the reconfiguration of productive capacities?

The above questions are re-adopted from Lorentzen (2016). The resoan for chosing to adopt theses qustions is that Lorentzen (2016) took an indepth investigation on lateral migration

and the themes that are investigated through his questions are also the main focus of this research paper. Thus the relevance of Lorentzen's (2016) themes (Absorptive capacities or firm learning, The role of foreign technology, Linkages and interactions and Industrial policy) are the reseans for adopting his research questions.

2.3 Sample

Three participants were interviewed for this study. Participants were selected based on their involvement in the National ventilator project and the sector they worked under. One of the participants was a senior engineer who was responsible for designing and manufacturing the ventilators from the public sector. The other two participants were project managers of the ventilator production, one from the private and the other from the public sector. Three in-depth interviews with a minimum of an hour-long with each participant were conducted. In the table below the details of the participants is presented. For the ease of presenting the data and protecting participants' identity, their name is replaced with participant 1, participant 2, and participant 3 and these IDs will be used when quoting and/or referring to the participant's statements.

Table 2: Details of the participants

Participants ID	Gender	Role	Organisation
Participant1	Female	Project Manager	SARAO (public)
Participant2	Male	Chief Engineer	SARAO (public)
Participant3	Female	Project Manager	NACAAM (Association of private sectors)

2.4 Data and Analysis

Once the interviews were completed with all the participants, the recordings were transcribed and coded manually. Thereafter the codes were themed in groups in a way that they answer the research questions and relate to the theoretical framework. The main categories that emerged are (i) reconfiguring and retooling local manufacturing capabilities; (ii) public-private partnership in reorienting local innovation and production efforts; (iii) actual

capability, production capability, research and development and investment; (vi) Innovative industrial policy and (v) Economies of scale.

3. Literature review

The study is focused on investigating the effectiveness and success of the National Ventilator Project in public-private partnership and knowledge asset transfer for ventilator manufacturing in the face of the current covid-19 crisis. However, the manufacturing process of ventilators is not a simple process for countries like South Africa which does not have prior ventilator production experience (Carbonaro, 2020). Thus innovative industrial policies, reorienting capacity toward the new (ventilator) manufacturing, applying knowledge and resources that have been used in other industry (lateral migration) are essential. Therefore, literature that is focused on industrial policy, literature on lateral migration (knowledge asset transfer), literature on public-private partnership and literature on global value chains are found to be relevant in understanding what it takes for South Africa's NVP to succeed (be able to manufacture ventilators on the timeframe that is set). Therefore, such literature is discussed below.

3.1 Industrial policy

The topic of industrial policy is wide and there is no universal definition of industrial policy (Oqubay, 2015). Industrial Policy is defined as a policy that is "aimed at particular industries (and firms as their components) to achieve the outcomes that are perceived by the state to be efficient for the economy as a whole" (Chang 1994, p.60). Chang's (1994) definition centralises on "selective targeting", 'strategic orientation" and "efficiency" with no attention to the country's level of development. On the other hand Pack and Saggi (2006) further elaborate industrial policy as any form of government policy or intervention that seeks to attract investment and resources in the productive sectors with high economic growth potential, which would not take place in the market equilibrium state. The main objective of industrial policy is to have an activist state that is determined to create "competitiveness and capabilities of domestic firms to improve the workings of the market, and horizontal intervention directed at promoting specific activities across sectors" (Oqubay, 2015, p. 18).

Furthermore, Shaohua (2020) emphasises that the role of industrial policy is "to offer external assurance for innovations to occur and be applied in the industrial system". (p. 59).

According to his explanation, private sectors do not have an incentive rather than increased profit for them to embark on innovative activities, thus, the state must intervene through industrial policies to create innovation and increase the competitiveness of the country's products in the global market.

Although not termed as industrial policy, policies that aimed at developing Britain's early manufacturing, thereafter, United States's, German's and other Western countries have been used in their industrialization processes (Stiglitz, Lin, Monga, and Patel, 2013**).** However, with the introduction of free trade in the late 18th-century industrial policy becomes to be the least prescribed policy strategy (if not actively discouraged) by the dominant economic power (Stiglitz, et al., 2013). Only Post World War Two with developing countries using industrial policies for achieving post-colonial independence and again after the 2008 financial crisis industrial policy becomes fashionable once more (Andreoni & Chang, 2016).

While industrial policy is as old as Britain's early industrialization there is no common consensus on how to use it amongst economic intellectuals. There are different theoretical approaches to IP. The neoclasial, new structural economics and heterodox perspectives are discussed below.

Neoclassical theory accepts industrial-policy measures only where the market allocates resources inefficiently (Cohen, 2006). The neoclassical perspective of industrial policy is limited to the state helping private investors with information externalities i.e. help investors identify where the countries' comparative advantage lies and invest in that sector by providing generalized support (Rodrik, 2004). Neoclassical theory justifies public intervention by market failures, largely arising from information asymmetries and incomplete markets, externalities, and increasing returns to scale (Cohen, 2006).

Rodrik (2004) argues that the best policy response to information externalities is that for the government to subsidize investments in new and non-traditional industries, however, the state must not pick winners as it might fall into the moral hazard and power abuse. According to the neoclassical theory the public authorities have two options as far as intervention is concerned: either they formulate a strong competition policy in order to restore conditions of fair competition in a situation close to full information or they put in place a strategic

industrial policy through which they play an active role in encouraging non-opportunistic behaviour in the industries concerned (Cohen, 2006).

The other case of market failure arises from externalities. Externalities create a need for public intervention, as illustrated by Arrow (1962), who showed that the costs of obtaining scientific information can be prohibitive, but when the information becomes accessible, its unit cost drops to almost nothing once the information has been widely disseminated. He also noted that the incentive for private-sector agents to spend on R&D is extremely low because of the difficulties in appropriating the knowledge created. In other words, the market fails in providing appropriate research incentives. In these circumstances, the state can play a role in getting incentives right, for instance, by subsidising R&D spending. Indeed, many authors (Cohen, 2006) have legitimised public intervention by regarding public aid as rewarding innovating firms for some of their contribution to public wellbeing. the rationale for public policy aimed at enhancing a nation's competitiveness and the contrast between horizontal policies, justified under neoclassical theory, and vertical or sectoral policies, discarded by neoclassical economists.

The standard criticism levelled against sectoral industrial policies is that the state has neither the necessary information nor adequate incentives to make better choices than the market. Since it also obeys a political rationale, it tends to prefer spectacular and demonstrative actions to effective and selective ones (Cohen, 2006). As it follows a sequential logic, it tends to misestimate the aggregate effects of its action, and in particular the negative long-term effects of the protection granted to certain firms and the negative impacts of the benefits granted to promoted sectors on other sectors (Cohen, 2006).

New Structural Economics (NSE) is also not far from neoclassical perspective except for its advice to identify future comparative advantages and develop industries for them while the role of the government in NSE is also limited to "facilitating industrial upgrading and infrastructure improvements" (Lin, p.193). Lin 2016 argues that the differences in economic structure for countries at different levels of economic development are a result of the differences in their endowment structure. The NSE advocates for a competetitive market as firms in an industry will be viable in an open, competitive market only if the industry is consistent with the comparative advantage determined by the economy's endowment structure (Lin, 2016).

Lin (2016) further argues that every developing country has the potential to grow dynamically for decades, and to become a middle-income or even a high-income country in one or two generations, as long as its government has the right industrial policy to facilitate the development of the private sector along the lines of the country's comparative advantages and tap into the latecomer advantages. For the government's industrial policy to achieve that desirable result, a change in development thinking is necessary.

On the other hand, heterodox economists emphasize the importance of "ambitious Industrial Policies" that is much more than providing information or facilitating infrastructure but also on the involvement of an interventionist state as far as creating "development banking; local-content management; selective seclusion (opening some markets to foreign transactions and keeping others closed); and national firm formation" (Amsden, 2001 p.125).

The economic rationale for the industrial policy includes (i) the empirical evidence that is available on the relationship between industrialization and per capita income growth (ii) labour productivity in industrialization is greater as compared to agriculture (iii) evidence also shows that the process of capital accumulation in manufacturing is one of the sources of economic growth (iv) the technological progress associated with manufacturing has a "diffusion" effect on the sectors and (v) most of all there is a productivity linkage and spillover associated with industrialization that results in rapid economic growth by improving productivity in other sectors too (Szirmai 2012, p.410).

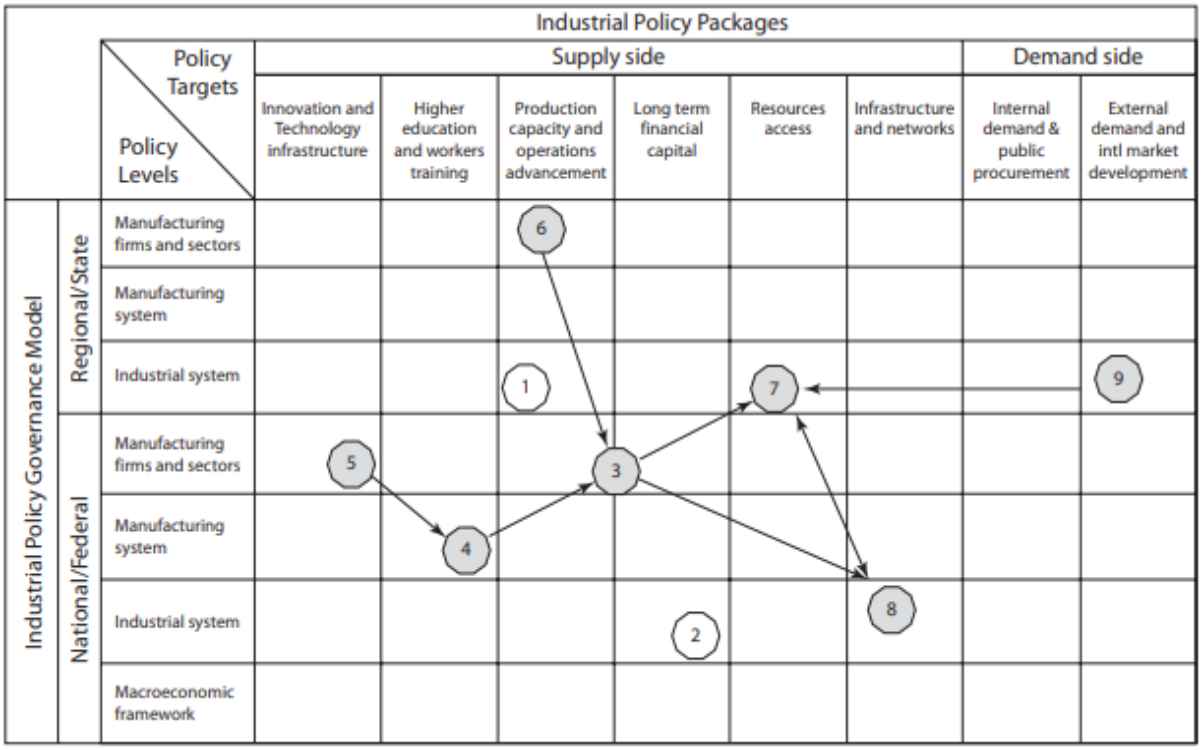
Industrial policies focus on the structural transformation of economic development such as promoting the manufacturing sector that is believed to have increasing returns to scale compared to sectors such as agriculture (Khan, 2009). Industrial policy is primarily about enhancing competitiveness by creating incentives and compulsions for firms and workers to improve productivity at constant levels of technology while facilitating technology acquisition (Amsden, 2008). Thus the accumulation of production capacities such as directing investment on identified manufacturing sectors, infant industry protection (using subsidy or/and tariff), complementary policy toward import-substitution and export-led growth, and spending on physical infrastructure are at the heart of economic perspective on industrial policy (Jenkins, 1995).

The East Asian countries are considered to be successful late manufacturers with "indigenously owned firms across a broad range of major global industries, capable of acting as first-tier suppliers to multinational corporations (MNCs) included chemicals, petrochemicals, electronics, steel, shipbuilding, cars or car parts"(Wade, 2018 p.525). The Asian experience entails that comparative advantage was not a given but a result of deliberate industrial strategies and capability building undertaken by the state that changed a good idea into a product (Khan, 2015). For example, regardless of having cheap labour, the textile industry of the 1960s Korea and Taiwan could not compete with the Japanese textile industry (Amsden, 2008). They needed "industrial policy and government economic intervention to help private firms build the asset they needed to complement their rock-bottom labour costs" without the structural change in the textile industry these countries would have been unable to compete with Japan's textile trade (Amsden, 2008 p.4).

The automobile industry of Brazil, Mexico, and South Korea is also a result of successful industrial policies, from manufacturing close to zero cars in the 1970s the South Korean automobile industry grew to produce over 1.5 million cars in 1990 (Jenkins, 1995). The common strategies used in these countries are autonomous, united, and highly interventionist states; high domestic market protection measures; import substitution and export promotion (Jenkins, 1995). Although there is no uniform industrial policy recipe across countries, the experience of these countries entails strategic intervention such as reduction in taxes for those who use locally manufactured components, an incentive for innovation and sector-specific assistance are essential.

Andreoni and Tregenna (2018) also provide extensive pieces of evidence on how industrial policies have been used to promote industrialization and economic development in specific sectors in Brazil, China and Malaysia. These countries used industrial policy to promote agricultural industrialization, improve technology through R&D financing and palm oil manufacturing respectively. The authors also indicated that industrial policies could be used for a specific sector or to promote general industrialisation. However, they emphasized that cooperation between sectors is important to implement the policy successfully.

Table 3: Industrial Policy Package Analysis; Andreoni (2016)



The policy matrix provided in the above table summarises that "the effectiveness of a single policy measure depends on its linkages with other policy measures acting upon the same companies, sectors and specific institutions. This implies that the policy effectiveness of a certain instrument might be improved by both/either using the instruments more effectively and/or by changing or introducing other complementary instruments. The combined effect of different policy instruments tends to be different from the one that the government can achieve by the independent implementation of the same policy measures in time" (Andreoni and Tregenna, 2018 p. 25).

On the other hand, Adreoni and Tregenna (2018) argue that countries that prematurely de-industrialise lost the opportunity of technological improvement, the capacity to add value in the global value chains and their level of productivity is jeopardised. They also provide evidence to that that South Africa is in the category of early de-industrialised countries. Thus the country is trapped in the middle-income group. According to their analysis, South Africa face challenges such as a lack of coherent industrial policy packages, the inability to select an appropriate instrument to improve production in specific sectors and the incapability to coordinate different sectors for economic diversification. Thus the country is unable to move into more technologically sophisticated segments of GVC and couldn't benefit from it as much.

In addition to that Zalk (2014) also indicated that South Africa's "support instruments and policy alignment has proceeded very slowly, even as the economy has been subjected to three major shocks: ongoing currency overvaluation and volatility, the global financial crisis and ensuing recession, and a domestic electricity supply and price shock" (sec 12.7, par 2). He further argues that successful industrial policy is beyond tax incentive and tariff reduction but a well-designed and country-specific solution. Nonetheless, he also argues that there is a promising industrial policy framework post-2007 in South Africa.

3.1.1 The role of the state in Industrial Policy

As shown in the above discussion to achieve the successful implementation of industrial policies, the state must manage the rents associated with industrial policy and other policies. Amsden (1997) also argues that the main role of the state in industrialization should be to move the focus away from getting "prices right" in the exchange market and to create a production market. A production market is a market that centralizes its focus on competitive assets that are essential to produce in global standards (Amsden 1997). For achieving a global standard production level the state must support and discipline domestic producers (Chibber, 2002).

The state also plays an essential role in creating trade and exchange rate policies that are in favour of local manufacturers (Amsden, 1997). As East Asian experience exhibits the promotion of learning by doing, attracting foreign direct investment, the provision of infrastructure, investment in productive capacities, technological upgrading and the creation of Multi-national Corporation were done by the joint effort of the state and the private sector (Wade, 2018).

Furthermore, Chibber (2002) argued that the success of industrial policy is dependent on the kind of role the state plays in the process of industrialization. For example in his examinations of the state's role in industrial policy, he found that the success of Korean industrial policy is directly linked to the internal cohesiveness and healthy bureaucracies of the Korean state while the opposite character of the state made Indian industrial policy a failure. Even looking at industrial policy in early industrialized countries, the states were the main actors in planning, protecting and promoting manufacturing industries (Dadzie, 2012). Moreover, Akyuz and Gore (2001) argued that the 1960s and the 1970s short-lived Sub-

Saharan African countries higher economic growth was because of the state's focus on industrialization.

3.1.2 Industrial policy in times of crisis

Literature indicates that industrial policies have been at the forefront in addressing supply shortages in a period of war (Nasson, 2018; Miyajima, 1992). During a crisis like a war shortage of supplies like manufactured goods is not uncommon (Nasson, 2018). The incident of 2020 where a shortage of medical supplies is experienced due to the covid-19 crisis is no different from South Africa's acute shortages of industrial goods and staple household commodities due to disrupted trade during the First World War (Nasson, 2018). Nasson (2018) presented that South Africa had embarked on import-substitution industrialisation to meet the domestic need for manufactured goods that used to be imported from overseas during the First World War.

Many countries use industrial policies during times of crisis. As Miyajima (1992) examined the industrial policy of Japan during the interwar period, combinations of different sets of industrial policies have been used by the Japanese state. During the interwar period, Japan has used Industrial Constructive Policy (ICP) for the process of building industries and used Industrial Organisation Policy (IOP) to encourage competition once the industries have been built (Miyajima, 1992). Therefore, there is no one size fits policy which is can be used universally during a crisis. However, policies may be crafted to meet the individual needs of a country depending on the crisis faced.

Kaplan (2011) presented that the success of knowledge transfer is highly dependent on the deliberate policies the government creates. He further argued that policies that are focused on enhancing linkages such as upstream, downstream, backward and horizontal are necessary for successful lateral migration. Furthermore, Feng (2019) found that industrial policy significantly improves the innovation efficiency of enterprises. Cheah and Ho (2020) also found a causal relationship between industrial policy and innovation capability. In their study, they presented that government-supported projects significantly and positively influence innovation outcome. Therefore sound industrial policy is necessary if public-private technology transfers need to result in continuous innovation outcomes (Cheah and Ho, 2020).

3.2 Lateral Migration

Lorentzen and Pague (2009) stated that lateral migration is a term first coined by Paul Jourdan and Miriam Altman to explain the process when "the knowledge base of a resource sector and its associated capital goods and services sectors are applied in other sectors not linked to resource exploitation" and the process takes place "when the gradual and continuous accumulation of knowledge bridges the resource and the knowledge economy through linkages of human and other capital" (p.7). As it is argued by Lorentzen and Pogue (2008) the process of lateral migration opens up development trajectories in the sector where knowledge is transferred. Also, Lorentzen (2006) emphasizes the need to innovate as "innovative capabilities are a prerequisite for sustainable growth and industrial competitiveness" (p. xii).

Although the theory of lateral migration is focused on the knowledge and capability transfer from resource-based sectors to sectors that are not resource-based in this study we would like to extend the theory from a perspective of knowledge and capability transfer from non-resource based to non-resource based sector. The link of lateral migration theory to our study is that to examine the knowledge transfer process that is needed from the South African Radio Astronomy Organization (SARAO), the automotive industry, the research institutes, the diving equipment space and other participants into ventilator manufacturing.

Lorentzen (2006) identifies four characters that are determinants for the existence of lateral migration namely "absorptive capacities", "foreign technology", "linkages" and "industrial policy" (p.21). Respectively the determinants speak to (i) the ability to upgrade into advanced technical skills through research and development (R&D) and competencies accumulated over time (ii) the contribution of foreign knowledge to the process of innovation (iii) the importance of systemic dynamics for knowledge intensification through linkages and interaction between firms, science institutes and universities and (v) the extent to industrial policies contribute to driving innovation for the success of lateral migration.

Furthermore, CCSI (2016) analysed lateral migration from a perspective of their strength, weaknesses, opportunities and threats as shown in the diagram below. Although lateral migration is important for transferring engineering skills from sector to sector lack of government support and the lack of long-term interest in knowledge sharing might jeopardise the diversification process. Therefore looking at NVP through the lens of these determinants

may be beneficial in understanding the success of knowledge transfer between SARAO, the automotive industry and other participants for the production of ventilators.

Image 1: SWOT analysis of lateral migration

Source: CCSI 2016, p. 47

3.3 Public-private partnership (PPP)

Since the beginning of privatisation in the 1970s, the role of the state in economic activities has been declining (Wills, 2018). However, in recent years the interest in public-private partnership both from academics and policy makers' perspectives has been increasing (Wang, Xiong, Wu and Zhu, 2018). Wang et al., (2018) further presented that with a total amount of just over 12 trillion Yuan, China had engaged in close to 10500 successful public-private partnerships by the year 2016. As China's economic progress is impressive, looking into the works of literature on PPP might be significant to utilise the value attached to PPP for a developing country like South Africa. Thus the purpose of this section is to present the reviewed literature on PPP.

The literature reviewed differentiates PPP from "privatization", "outsourcing", and "collaborative governance" in a clear manner. Wang et al., (2018) distinguish these three factors from PPP as followed; (i) while privatisation is about the complete or incomplete transfer of ownership from the public to the private sector with the responsibility of production given to the private sector and the government has given the role of regulatory, there is no transfer of ownership in PPP (ii) while outsourcing is a once-off no risk attached unilateral assignment, PPP involves risk-sharing and long-term collaborations and (iii) although one of PPP's requirements is collaboration, "PPP project's most important goal is often to achieve coordination, agreement, and joint production, rather than to achieve decision-making consensus" (p.302). Overall, "PPP requires a lower degree of the collective decision-making process than collaborative governance, but higher than privatization or outsourcing" as Wang et al., (2018) summarised it (p, 302).

According to Wang et al., (2018) PPP is defined as a "durable complex cooperation between public and private sectors aiming to supply infrastructure and public service" (p. 302). One of the characteristics of PPP is that to achieve the goals set; both parties share the benefits and risks that are attached to the project (Wang et al., 2018). And one of the benefits of PPP is to overcome the lousy process of procurement in the public sector (Teismanand Klinj, 20002). Furthermore, Osborne (2000) expands the idea of PPP to new governance phenomenal than just cooperation. In the field of economics, PPP is widely seen as a micro-level partnership that looks into the performance of the cooperation in terms of investment opportunities, the procurement process and the overall project performance (Wang et al., 2018).

Moreover, the literature also shows the main advantages of the partnership between the public and the private sector. The main advantages found are (i) increase the availability of the necessary investment for the project to be successful; (ii) to ease the exchange of skill, technology and improve innovation; (iii) to lower the burden of risk one participant carries and (iv), to create a long-term market opportunity (Tang, Shen and Chang, 2010). Thus PPP's in NVP is looked at from this perspective.

3.4 Global Value Chain

Like never before the share of international trade has been increasing in the 20th century (Gereffiand Fernandez-stark, 2011). Not only is that but the global firms, workers and

consumers are highly interlinked to one another (Gereffi and Fernandez-stark, 2011). The process that interlinks these entities with the sequence of value addition is called Global Value Chain (GVC) (Gereffi and Fernandez-stark, 2011). Furthermore, advocates of GVCs like Gereffi and Fernandez-stark (2011) argue that if they are done gainfully GVCs can contribute to capability building, job creation, poverty reduction and as being a "stepping stone for firms and workers in developing countries to integrate into the global economy" (p. 2). Thus they support the dispersion of the sharing of international production across countries.

However, Strange and Humphre (2019) argue that the gains from GVC disproportionate as lead firms reap higher benefits than their partners. That is because lead firms have control over their GVC partners and usually have a monopoly over the pre-production and post-production process which hinders their GVC partners from technological upgrading and diversification (Strange and Humpher, 2019). Depending on which end of the GVC a firm is, patents affect the benefits from GVC. Zolas and Lybber (2014) found that for developing countries that are at the bottom of the value chain, intellectual property negatively impacts a country's technology diffusion, knowledge transfer and competition (p.1).

Additionally, literature written post-Covid-19 exposed the weakness of GVCs. Fourtunato (2020) argued that "the COVID-19 crisis has amplified profound fault lines in the functioning of global value chains (GVCs) and exposed the fragility of a model characterized by high interdependencies between leading firms and suppliers located across several continents" (para.1). He further argues the temporary export bans combined with the international closure of borders initiated the idea of self-reliance for essential products such as medical equipment. Nicola, Timmis and Akhlaque (2020) further argue that the most important thing about production isn't where it can be produced cheaply but where it can be produced to be accessed easily. They emphasised that in light of a crisis like Covid-19 where countries close their borders and essential equipment are scarce, accessibility is what matters the most than off-shoring and off-sourcing. Thus looking into GVCs in light of uncertainties is important.

4. Findings

The purpose of this chapter is to present the findings from the case study analysis and to answer the following research questions:

RQ1: To what extent has the NVP been successful in reconfiguring and retooling local manufacturing capabilities in an attempt to respond to the Covid-19 Crisis?
RQ2: Is there significance in the partnership between the state institutions, public organizations and the private sector in reorienting their innovation and production efforts in the covid-19 crisis?
RQ3: Does South Africa's manufacturing industries have what it takes i.e. actual capability, production capability and investment to produce ventilators if not is there capacity building (learning by doing) taking place?
RQ4: Is there an innovative industrial policy? If yes, is it long-term (does it create future manufacturing possibilities) or is it only focused on combating the current medical equipment shortage?
RQ5: Are there economies of scale for manufacturing ventilators? If not, how is it intended to be built and are there defined policies that are in place to promote economies of scale?

Therefore the themes that emerged from the interview and the findings concerning the above research questions are discussed below.

4.1 Reconfiguring and retooling local manufacturing capabilities

Before embarking on the discussion of reconfiguring and retooling process, it is important to look into the original duties of companies involved in the project. National Association of Automotive Component and Allied Manufacturer (NAACAM) is a public company in the automotive industry. Their member base is parts of equipment suppliers to Original Equipment Manufacturers (OEMs) for local assembly and exports. The main objective of the association is to increase the local share of component suppliers to OEMs. Therefore, NAACAM's member company's main duties are manufacturing automotive components and assembly.

The other organisation involved is the South African Radio Astronomy Observatory (SARAO). As explained by participant 1 from SARAO, the state-owned organisation is a "facility of the National Research Foundation, is responsible for managing all radio astronomy initiatives and facilities in South Africa, including the MeerKAT Radio Telescope in the Karoo, and the Geodesy and VLBI activities at the HartRAO facility. SARAO also coordinates the African Very Long Baseline Interferometry Network (AVN) for the eight

SKA partner countries in Africa, as well as South Africa's contribution to the infrastructure and engineering planning for the Square Kilometre Array Radio Telescope". Therefore the organisation is in space telescope manufacturing.

The national ventilator project demonstrated the benefits of transferring skills and knowledge from one sector to another to reconfigure and retool local manufacturing capabilities. As it is indicated by participant1 from SARAO the same kind of skills and knowledge used to build telescopes in the Northern Cape were coordinated precisely in a similar manner to produce the ventilators. Furthermore, she describes how SARAO began the process of ventilator production;

"The South African Radio Astronomy Observatory was mandated by the Minister of Trade industry and competition, to manage the project on their behalf. So, it wasn't necessarily our initiative as such. And what we primarily provided was the project management, systems engineering, and industry partnership, expertise, as well as other engineering expertise. And so more than anything, I think what it just demonstrated a lot of what you could do if you take the knowledge that is not even relevant to a specific area but apply the same systems, to have a successful project. So those skills are the skills we use to build a telescope in the Northern Cape and just coordinating things in precisely a similar way. So the project had two components. So we started with a stream one. And stream one was focused on the non-invasive ventilators. And then we subsequently also initiated stream two through which was a focus on the rest, the bi-pap, and the more invasive ventilators"

As indicated in her description above the South African Radio Astronomy Observatory (SARAO) had a successful experience in building a radio telescope called Meerkat, they built Meerkat with no prior experience in building telescopes. The senior Engineer at SARAO stated that *"I work for SARAO, I do not have much to do with the medical industry but also when we started with radio astronomy we knew nothing about radio astronomy. One of the things we did in the development of Meerkat, Meerkat is now quite widely being seen as the most capable radio telescope in the world. It is a massively complicated instrument to build."* As the quotation clarifies, Participant 2 indicated that SARAO had no experience with manufacturing medical equipment before the NVP project, nevertheless their experience in building a much more complicated setup for Africa's biggest telescope gave them the confidence to attempt building the ventilators. He further emphasized that the most important

ingredient they needed for manufacturing ventilators wasn't medical background but discipline, system engineering, understanding user requirement, translating the user requirement to engineering requirement and then filtering it down to a component and finally testing the component against the user requirement. Therefore according to participant 2 from SARAO, the most important element in manufacturing a component from scratch is a competent engineer who well understands the requirements presented.

As SARAO was mandated by the Department of Trade and Industry to manage and lead the project, selecting partners to working in the project was SARAO's responsibility. Participant 1 from SARAO points out some of the criteria's used in the selection process, which were; the ability to meet the detailed user requirement specification, readiness to implement the project, available technical capacity and entities that already had licenses to manufacture medical devices. She further elaborates that out of the 91 applications received from both small and big businesses, only six were selected. She explains the selection process as follows;

"*When we did the call, we received 91 responses to the initial call. And this was from, small businesses that had some manufacturing capability and wanted to contribute to the project to really big companies in the automotive and in an aerospace sector that have infrastructure and manufacturing capabilities that they could use for a project like this. Because of the limited period, the project did manage for the required time to refocus the manufacturing towards medical devices, some of those manufacturers will go back to their core business, so for instance, the CSIR which is a lot of the ones that we did procure came from their Consortium, the devices were manufactured by a medical device company that already is on in the medical space had all of the regulatory approvals to manufacture this. So I think while it might not have completely shifted, going forward is going to depend on what government says to do with it. Because what it has proven is it can be done because we didn't have any other choice but to produce locally with the right policy directives and the right support you can create a home sector that sustains what the economy needs."*

According to her, the small businesses had some manufacturing capabilities while the big businesses mostly came from the automotive and aerospace sector had infrastructure and manufacturing capabilities that could be useful for the NVP. They chose companies with prior manufacturing experience and available production capability because of the limited

time available and uncertainty of the longevity of the project. As per her description the public organization CSIR had produced medical equipment prior to the NVP and had met the regulatory requirement. Thus the majority of the work was done by CSIR.

One of the participants selected to participate in the NVP manufacturing was the National Association of Automotive Components and Allied Manufacturers (NAACAM). NACAAM had already started the process of manufacturing ventilators even before selected to participate in the NVP by DTIC. As is indicated by participant 3 the motive behind NAACAM's attempt to manufacture ventilators was to address the health crisis but most importantly to make sure that their staff can return to work during the stringent lockdown as most of the workers were contract-based. The participant stated their reason of involving in ventilator manufacturing as follows;

"The risk for us is, as much as many of the tier ones are big multinationals, they are still going to struggle with issues of cash flow, meeting their wage obligations, and all of that stuff. So we started to think a little bit differently about what could we use to absorb the spare capacity that may exist productively, number one, to address the crisis, but number two, and most importantly, to make sure their staff can still go back to work. So we started looking, we started seeing all those stories globally, Ford in the US starting to make ventilators and in the UK, and all of this stuff, so we put together a little project team within the NACAAM's office, and one of our NACAAM member companies and Rand York castings."

Participant 3 further elaborates NAACAM's ventilator manufacturing process which began with putting together a little project team called SAVE-P within NAACAM's member company's and proceeded to appoint Rank York's Managing Director to lead the project as he has prior experience with a similar social development project and still had the network that could be used for ventilator production.

However, as indicated by participant 3 the process was a challenging one. NAACAM's participant stated their challenges;

"*It was first determining the kind of ventilator that we needed to the manufacturer. Because when we look globally, a lot of the companies, we saw like a Rolls Royce and Maserati were making ventilators but they were choosing to make a very invasive, electronic-based kind of ventilator. And our challenge is understanding, the South African landscape, we know the*

electricity supply is not secure. So having an electrical system is probably not ideal. We anticipated that it was likely that, if we had like New York levels of infections, where hospitals cannot incubate people, we're going to need to work in field hospitals. And these very sensitive electronic kinds of systems don't work well in that space. But fundamentally, for us, we knew that the ports were closing. So we could not make a system that required us to rely on an imported electronic component. Because the electronic sector in South Africa is very shallow. We can make white goods like TVs and fridges and stuff other than that capability is very low. So we didn't want to pick a kind of model that required a lot of this imported content, because we didn't know if we were able to access it. What happens if they close the harbours? How do we deal with and many of the suppliers would have been in China or the Far East anyway, with the economies shutting down? So what we decided to do was, to pick a more mechanical model, and probably an older specification, that would be easier to train nurses and doctors on how to use it. Because the last thing we wanted is, developing this model that was particularly difficult for healthcare workers to use because then the likelihood of using it will be very little"

She outlined challenges such as identifying the kind of ventilator that is compatible with South Africa's landscape such as unsecured electricity supply and finding ways to produce a ventilator without an electronic component. The reason provided for avoiding an electronic component was the disruption of the global value chain wouldn't allow accessing electronic material easily and that the South African electronic manufacturing sector was shallow and relies on imported materials for manufacturing. Participant 2 from SARAO also added that SAQA approval requirements get complicated if the device has electronics or software in it, thus, a simple device without electronics that speaks to the need was chosen by SARAO too.

Nevertheless, NAACAM managed to overcome the challenges by cooperating with different experts from medical practitioners, automotive components manufacturers, research and development teams, logistic networks, engineers to state organizations. NAACAM's participant explains how the process of production began;

"*Eventually, we managed to get the drawings from them* (a British company). *We then sort of assembled a little project team of volunteers from within the NACAAM member companies that had R&D expertise that could help us convert those into CAD drawings. Because the thinking is that, the automotive sector has a sophisticated understanding of logistics networks*

and value chain optimization and things because OEMs are sitting in like one city, so BMW is up here in Roslyn, but they are sourcing components from across the country on adjusting in time process. So we thought that was probably the best approach for us to have the ventilators being assembled in one main point, and having suppliers across the country shipping in the specific component for it. So once we got the drawings and we understood what were the materials, what were the technical specifications, we generated the CAD drawings, we then went out into the automotive sector and said, Ford, there is a pressed metal part that is required inside a ventilator, and it could have been the box. So we went to those companies to then try to figure out with your existing tooling that you have the existing raw materials that you have, are you able to sort of reconfiguring that tooling to be able to manufacture this medical device component."

As stated above eventually NAACAM picked an older specification and a more mechanical model that was out of patent from British. After acquiring the model at no cost they created a research and development team to convert the drawing into a CAD drawing. Participant 3 emphasized that the existence of sophisticated logistic networks and value chain optimization enabled the automotive sector to identify the right materials, technical specification and reconfigure the existing tooling to make the components needed for the ventilators. She further added that the retooling and reconfiguring process only took 4 months of intensive training.

Although the process was completed in a short period, it went through lots of adjustments and hard work. The participant from NAACAM provided detailed information about the process;

"*We were more concerned at this point about just understanding can I go from making a door panel to a box panel inside a ventilator. Can I go from making a clutch spring to an air pocket spring in a ventilator? So we spent probably three to four weeks sort of intensively working on this. And I must say most NACAAM companies have put their hands up and volunteered to support even if they couldn't make a component. If they were deployed engineers or R&D specialists could go and help another supplier to do this. So eventually, after we went through these various rounds of this, Justin from Rand York was leading this technical side of the project of trying to figure out which suppliers can make which components and figure out if we can access the raw material. While that was happening from a non-campus victim, we were trying to figure out how to get them inside the national*

ventilator project, because we realized there potentially was a scope for us to supply into the private sector. But to be honest, private sector hospitals and clinics will have the cash and were able to import the ventilators directly from wherever they wanted it. So that was not ideally, when we want to the service, we wanted to figure out how we could get this into public health care facilities. So I spent a lot of my time working through the BUSA channels through, the CSIR, and eventually, we pull into BUSA had started these personal protective work streams. We're different work streams, we're going to focus on the local manufacturer of different kinds of PPE. And the NVP was one of those projects. So the comical thing is when we started the NVP, they realized the automotive sector has manufacturing capabilities. So all of these things are happening at the same time. So the auto guys started supplying face shields, when the Department of Health and SABS looked at the quality of the product, they realized that an automotive quality standard is a lot higher than most of the medical standards that SABS as a unit accredit to. So when they saw that on the ventilators, they then came to us and said, how can we expedite the work on the ventilators? What is the help that you need? Because clearly, you have the technical capability. At that point, we were not struggling with raw materials, because the base raw materials we already use in autos, we didn't struggle with tooling. Because all of our automotive companies have tool makers in the house that have been there for many years, they were able to build new tools and things sort of quite quickly. So that was not the challenge. The issue was about us being able to once we assemble the unit to get it accredited because you can't have someone on a ventilator that is not a medically tested thing. So we spent a lot of our time working with these guys to understand, could we augment these testing requirements slightly in the context of a national state of emergency to figure out how to do that. So all these things are sort of happening in parallel, so eventually, we had developed the sample of the first ventilator we had to remember the NVP, it was like you had to apply expressed an interest in submitting a whole bunch of documentation and all of that stuff. We did all of that our units had to go through the testing processes, the facility was audited. So the company that assembles the final ventilator is a company in Roslyn called MCR manufacturing. Now, normally they make brake callipers normally it's very dirty. It's gritty, it's not medical. So what MCR had to do is we cleaned out the entire logistics warehouse, we removed everything that was inside there. We like epoxy the floors, we put in human control, dust control air systems, we put in decontamination entrances and all of that stuff. So we built a mini, a highly sanitary medical device kind of facility in an abandoned warehouse that's at that facility. So we did all of that because we realized if we walked into a dirty, grubby foundry environment, there is no way

we were going to get our accreditation here, even if we had earmarked an area, so we thought it was probably safer. So we did that. MCR had been contacted all this stuff that we're now sitting at home because we were in level five lockdown, we cannot allow you to go to work during level five. So we had to call 15 people it moved up to about 25 after that brought them back in because they needed to be trained on how to assemble this ventilator because remember, they were assembling curriculum was before, it is very different."

Her detailed explanation of how the process began also indicates that the automotive sector has the technical capability, production capability and economies of scale to diversify into medical equipment manufacturing. However, finding the market to supply their ventilators getting accreditation was a challenge for NAACAM.

Finally, a NAACAM's member company called MCR Manufacturing did the assembly. As explained by participant 3 MCR was a brake callipers manufacturer which then converted to a medical device facility until the manufacturing of ventilators was completed. The image below shows the ventilator that was produced by the project team NACAAM created followed by the table that provides the details and specification of the ventilator.

Image 2: the ventilator called CPAP 100 manufactured by NAACAM's team, SAVE-P

Table 4: The details and specification of CPAP 100

Manufacturer	SAVE-P consortium
Device Name	CPAP 100
Overall Dimensions	270 mm (width) x 165 mm (height) x 140 mm (depth) (blender unit only, including ports and controls)
Weight	4.0 kg (excluding stand and hoses)
Gas ports (3)	1. High Pressure O_2 supply (SANS 1409) 2. High pressure medical air supply (SANS 1409) 3. Patient circuit outlet (ISO 5356 22mm)
O_2 and air supply pressure	300-400 kPa
Controls (3)	1. Gas flow on/off 2. Flow Rate (dial scale 15-60 lpm) 3. FiO_2 (dial scale 21-100%)
FiO_2 adjustment range	21-100%
Flow to patient circuit	15-60 lpm

As shown on the above image and the specification table, NAACAM successfully reconfigured and retooled its manufacturing capability into producing ventilators from its original automotive component manufacturing setup. Thus NAACAM provided 2000 out of the 20 000 ventilators required by the DTIC. The other 18000 ventilators were manufactured by the Council for Scientific and Industrial Research (CSIR) and its partners. CSIR worked closely with SARAO in the procurement process and partnered with other medical device manufacturing company that already had the required licences to manufacture ventilators.

Unlike NAACAM the design used by CSIR was mostly designed by them, they designed their oxygen mixer and developed a hood that could be connected to the device and worn over the face. Participant 1 from SARAO explains how CSIR worked with a diving equipment manufacturer in the designing process:

"*They also design their mixer and they are in the diving equipment space. They use their knowledge of how to provide oxygen to divers, deep-sea divers to not only come up with oxygen mixer stuff but also came up with the hood that could be connected to the device and*

worn over. And to provide oxygen. This was primarily really just an off the shelf mask, but they were local companies that do with designing mask again; this would come from the diving industry essentially. So the design is either what they use already in the medical space, the face mask is the one you normally see that just covers this, the full face mask does cover. And that the full face mask design was made by expertise from the diving industry. So I think it was a really, very broad meet depending on what they came up with."

As indicated by Participant 1 from SARAO that the full-mask used was designed by expertise from the diving industry. She added that materials used in medical equipment are peculiar, companies involved from the automotive and aerospace sector had to adjust quickly to the medical regulatory requirement and reorient quickly. The image and the table below present the design and specification of the ventilator produced by CSIR, SARAO and their partners

Image 3: the ventilator called UCL Ventura manufactured by CSIR and partners

Table 5: the details and specification of UCL Ventura

Manufacturer	Various (Gabler, CSIR/Sabertek)
Device Name	UCL Ventura
Overall Dimensions	160 mm (width) x 130 mm (height) x 50 mm (depth) (blender unit only, including ports and controls)
Weight	0.4 kg
Gas ports (2)	1. High Pressure O_2 supply (SANS 1409) 2. Patient circuit outlet (ISO 5356 22mm)
O_2 supply pressure	300-400 kPa
Controls (3)	1. Gas flow on/off 2. Flow Rate (no dial scale) 3. FiO_2 (no dial scale)
FiO_2 adjustment range	30-100%
Flow to patient circuit	0-120 lpm
Indicators/Alarms	None

Therefore the above images and tables are evident that the ventilators manufactured were successful in their execution. Furthermore, participant 1 from SARAO emphasised that the project succeeded because SARAO, CSIR and NAACAM together with other companies took the initiative to manufacture locally with the right know-how, policy directives and the right support, thus a domestic manufacturing sector was created. Participant 2 from SARAO also added that the success of the reconfiguration and retooling process as a result of capabilities of the organisations participated, strong public-private partnership, the solidarity fund and the role of a state institution in easing bureaucratic processes.

4.2 Public-private partnership in reorienting local innovation and production efforts

As is discussed in previous sections the DTIC was the first institution that drafted the NVP and mandated SARAO to manage the national effort required for the local design, development, production and procurement of respiratory ventilators to support the government's response to combat the COVID-19 (coronavirus) pandemic. As participant 1 indicated SARAO worked with several public and private institutions in executing its mandates, institutions such as Sector Education and Training Authority (SETA), University of Cape Town, Stellenbosch University, Central University of Technology and others

volunteered to facilitate research and development program on how the required manufacturing skills can be built and strengthened. She further emphasised that;

"*Everyone was just finding the right partners, working with the right partners, implementing what they needed to do through some sort of partnership. So I think this was a good demonstration of, if you bring the right partners to the table, you can get a lot more done. I would agree* (partnership was important for the project). *I mean, the mandate to get the project done came from the Department of Trade and Industry, then we had stakeholders in the research base, like CSIR. And then we had a whole lot of small companies, IT companies getting involved. The solidarity Fund, which is the private sector, led the initiative and then SARAO. We interacted quite a lot with the private hospitals as well, in, finding what solutions would work for them. And some of them had perveusiouly procured the products that we produce through this process. I think, a lot of inter stakeholder engagement in partnerships that we were making made the project successful. With policy directives and the right support one can create a home sector that sustains what the economy needs."*

Participant 3 from NACAAM also indicated that volunteers such as medical experts from the South African Society of Anaesthesiologists (SASA), the Britain Company that provided the design at no cost, the Department of Health that provided a high level of support, DTIC which helped to avoid red tapes and other partners helped reorient local innovation and production effort to succeed. She emphasised the importance of public-private partnership;

''No chance anything would have happened without partnership. Zero, because as a private, I come from the private sector. We have absolutely no influence or authority in any of these public sector domains. We had no muscle with SABS, we were not going to be able to talk to the medical regulators. So we would have been able to manufacture a unit, I'm sure, getting it approved and getting it authorized to be supplied in that would have never happened that NVP order never would have happened. So for us, I think it was a mutually beneficial thing, the public sector, I don't think would have been able to consolidate the industrial capability to make the unit, I think we wouldn't have been able to navigate the regulatory and compliance side. So that's why we had to work together quite closely. And I must be honest, even within departments like the DTIC, they have multi-sector experts, they have an autos desk, or plastics desk, or metals desk. Those people that are sort of sector specific, experts were critically important here, because they understand the landscape, they understand the

supply chains, the main player, the regulation requirements, so we leaned quite a bit on these people for guidance and networks. I'll be honest, the success of this project was our ability to leverage existing institutional networks. Without that, we wouldn't have been able to do it. And that's why that company like RAND YORK, would never be able to do it by themselves. I mean, they manufacture one kind of metal project for a car, there's absolutely no way they would have the network the relationship, which is why he came to us and said, This is what I want to do, how can you help me because of the nature of our association is such a spread of different kinds of companies. So even those that didn't contribute to making an actual component, just provided expertise that sits within those companies. So given an example we have all the tire manufacturers are NACAAM members, you know, Goodyear, Kunti, Bridgestone, as much as they could never make us anything that went into a ventilator, their rubber and plastic engineers were critically useful in helping us in this project, these guys have gone studied PhDs at global universities in this topic. So the advice and sort of helping us lead some of this were tremendously critical, even though their companies never made a component. And I think one private sector company would not have been able to leverage that kind of network quickly and also at no cost."

All participants voiced similar opinions when it comes to private-public partnership's role in the success of the project. Participant 2 from SARAO specifically stated that *"I still believe if the government tried to do this purely as a government project, it might have not planned as well as it did now*". Thus the partnership between DTIC, SARAO, CSIR, small companies, large companies, IT companies, solidarity fund, NAACAM, private hospitals and other stakeholders engagement highly contributed to the success of the project.

4.3 Actual capability, production capability, research and development and investment

The interviews conducted revealed that the manufacturing process of the ventilators took less than 6 months. Given no prior ventilator production experience, the short period taken to complete the manufacturing led to examining the capability and investment capacity of local manufacturers. Few questions about capacity and investment availability were directed to all participants and the findings indicated that the South African manufacturing sectors have capabilities to diversify into medical equipment production.

Participant 3 from NAACAM emphasised that actual capacity already existed as she stated that "*We didn't procure new kinds of raw material, we didn't hire new human, we didn't have to buy software, and we didn't have to do any of those things. So for us, I think that also speaks to the success of our ability to do this is because the existing infrastructure was already all in place... we have the technical capability*". She further added that industrial knowledge and meeting quality standard was embedded in the automotive sector;

"So as an order came in, we sort of responded. Coming back to your question on the reconfiguring and the retooling, I think what we learned through this process is that you know, the automotive sector probably has the deepest industrial technical knowledge in the country, just because of the nature of the products that we manufacture. You know, many of our OEMs are not only manufacturing for the domestic market, certain OEMs like BMW and Mercedes Benz probably 80% of what they produce is exported to Europe or South America, whatever the case may be. So we have to be able to meet the quality standards and the reliability standards and it showed that you know, the automotive sector can do more..."

The suggestion from participant 2 from SARAO is no different from the other two participants. He mentioned that the capacity to manufacture for the current requirement and future market is present. In his words;

"*We have now industrialised the injection moulding portion of this. We can build hundreds of those units literally. It is not necessarily required because as it is we are close to having building 18000 of the CSIR unit and 2000 of the SABB units but if there is some market, that is one of the things DTIC looking for whether there is a market for these things outside of South Africa but we can produce these in numbers, we can produce according to specifications, we can produce them very cost-effectively."*

Additionally, the information provided by participant 1 from SARAO indicated that, manufacturing skills are abundant in the country except for some adjustment to fit the medical equipment requirement. She stated that "i*n terms of on the manufacturing side, I do not doubt that there's sufficient capacity in South Africa to do a lot more medical devices. There might be challenges overcoming the regulatory hurdles."* It wasn't the only participant 1's emphasis that the regulatory process was challenging, participant 3 also alluded to the same challenges that existed within NACAAM when she stated that;

"So I mean, effectively reconfiguration retooling was not a challenge, capability existed, raw material existed expertise existed. But I think for us that single biggest challenge was navigating those medical standard requirements because they're just so different to what we were normally used to."

Therefore actual capabilities and production capabilities were present in the sectors. When it comes to research and development and investment, all participants stated that the government was the main role player. However, there was a shortage of skills in the face shield design which needs further R&D. For example; participant 2 from SARAO indicated that;

"On the patient circuit side there were components like masks and so forth that was a bit of a challenge to design as well. Initially, we wanted to produce those masks locally as well but the local units we could get weren't quite good enough. It didn't seal well on people's faces, there was a leakage on the side and the consumption becomes so high. So those were for example imported but that was an existing supply chain. That was masks already supplied for, the challenge was getting the number, to get the shipping done when there were fairly strict restrictions on shipping. In that regard, we got support from DTIC to get shipments cleared through customs and things like that. That was an example where the state body could cut down on bureaucracy. For the rest, it was mostly local development"

4.4 Innovative industrial policy

The surprising finding that was revealed through the interview was that there was no specific industrial policy crafted for the NVP. Participant 2 from SARAO explains how the procurement process was undertaken without a specific industrial policy;

"I wouldn't say there was a specific industrial policy. It was more the development process that was defined quite well. I think in terms of industrial policy it also ties into procurement to quite an extent. So obviously time was of the essence but what we knew from day one was a year from now people will come and say how did you work this procurement and this and that. And your procurement will be evaluated in an environment a lot different than when it happened. When it happened this emergency, pandemic and so forth and afterwards

everybody is calm and say why you didn't do this and that and so forth. Part of your job is to make sure that you don't use the pandemic as an excuse not to practice good governance, you have always got to practice good governance. We pretty much followed BFMA and ultimately we had proposals to the solidarity fund they had to fund this thing and you know they had to approve the various procurement process. That was based on the capabilities of the organisations, previous experience, price and how the environment looks like and that was a strong consideration. They were eliminated because of that. I am very comfortable to say that we practised good governance on this and you all the documentation and motivation stuff is there if a year from now everybody challenges us on that."

However, as indicated by participant 3 from NAACAM, there was an industrial policy used in the project that was specific to the automotive sector that incentivizes the automotive sector to manufacture components locally than just assembling imported components. The aim of this policy is that to increase local component manufacturing. Thus as participant 1 from SARAO indicated that the policy was "handy" for the NVP. She explains the benefit by stating that;

'I will say that maybe we benefited from some of the industrial policy that supported, for example, the automotive industry, there's, you know, a very clear policy that government has is in place to support an industry like that, and that capacity came in handy because I think a lot of those manufacturing companies, we are well equipped in a position to, you know, really realigned to support any initiative levels."

Participant 3 from NAACAM explained what the policy is and how it benefits both the automotive sector and the NVP;

"And as I said to you, a lot of components in the auto sector are currently imported. So the master plan is asking us to get to 60% local content by 2035. We're currently sitting at around depending on who you talk to 35-36% local contents, it's almost a doubling as required. But what that means is we have an incentive structure through the DTIC, we have something called the APDP, which is a production incentive that components suppliers get, the higher your local content, the more of these credits that you get that you sell on an open market and you can claim it as cash. So there is a financial incentive for you to localize. So what does this mean in the context of the ventilator? It means that if I am currently running a

company that makes seating systems, and I'm importing half of what I need, there are active tax incentives available for me to localize new content. So what does that mean? It means I may look at the seat and say, Okay, this headrest is imported. How do I reverse engineer and work with a South African company to produce a sample go to my head office and say I have a reasonable viable alternate. So because of this sort of drive for localization in the automotive sector, where people are having to undertake their R&D…"

Furthermore, participant 1 from SARAO adds that if future medical equipment manufacturing has to flourish the state has to create a specific industrial policy for the medical equipment manufacturing sector. She stated that;

"Going forward, the government has an opportunity to create a much better and more robust industrial policy that allows medical sectors to become a lot more agile, you know, in terms of how we regulate the industries in terms of the support mechanisms that are in place, and the ability to support and enable the industry a lot quicker than we currently. So I think there is an opportunity. I wouldn't say necessarily, there was a specific policy that supported the medical industry in this in this instance, a, but I would say that in the fact that they exist for other sectors enabled for this to happen."

She further elaborates on the specific areas that government policy is needed. Although she supports the work the DTIC has been doing to support innovation, she believes that a lot more intervention is needed to ease the certification process and create a long-term production opportunity. She noted that;

"I know that the DTIC has been working on trying to create a much more code for supporting innovation. As I said, I mean, I think an ongoing discussion in terms of how do we enable this going forward is needed? How do we find a mechanism, for instance, support companies to get the CE mark, all of that has been around, you know, now is the chance actually for the government may be to intervene and create a mechanism to allow, to enable a lot of this type of thing happening. Even though there was a framework on innovation or commercialization of technology release back then, not sure that the implementation has been effective fully up to now. If I was on that side of the fence, I think I would focus on trying to learn from this and then seeing how we can implement programs going forward. To

make sure that this is long term support as opposed to something that only comes about when this does an emergence."

The reason for the need for industrial policy and government support for the development of medical equipment manufacturing is well explained by the participant from NAACAM. She elaborated that;

"So in the NVP, unlike some of those other pp workstreams, because we already had the facilities, we already had access to the raw materials, the large businesses had access to cash flow, we didn't need any kind of industrial development, financial support of any kind, you compare this to other, they were trying to make nitrile gloves. Those facilities don't exist in this country at all, it would have been starting a Greenfield facility. So those guys had to go in and figure out in the chemicals master plan, what can they do? Can the DTIC potentially offer an incentive? Is it an IDC issue? We luckily didn't have to do that. Because we didn't procure new equipment. We didn't procure new kinds of raw material, we didn't hire new human, we didn't have to buy software, and we didn't have to do any of those things. So for us, I think that also speaks to the success of our ability to do this is because the existing infrastructure was already all in place. You know, going forward, though, I think if we're going to look at this as a long term, sort of diversification opportunity, and potentially an export opportunity for the suppliers, I think there's going to need to be some kind of incentive in that exporting space because one of two things could happen, right, the autos guys could say, the auto sector recovers. COVID is not a problem. We are done. We're going back to what we do. But some smaller companies may realize this could be a bigger opportunity. The risk is they can't grow the ventilator component business, largely inside their existing facilities. Because our OEMs and tier-one expect you to have a minimum available capacity at all time, should they be shifting. So you can't suddenly go from making 10% ventilator components to 40%. And your auto customers think it's okay, those guys are going to have to now move into new facilities and that I think they're going to need to require some kind of industrial policy intervention there and incentivization of some kind to be able to do that. I mean, to be honest, if you went to a normal defy, like an IDC based on you have secure orders, you know, and as long term potential they would probably fund that. But you know, within like an IDC is medical devices in a core mandate in their prioritized sectors. There's probably going to need to be something and in my mind, like how the South African automotive sector has our master plan. You know, they're currently doing one in clothing and

textiles. They did one I think for chickens, they doing wonderful furniture, I think a medical devices master plan must be developed because our autos master plan, sets these targets in terms of local content and transformation or whatever. But likewise, it has a supporting incentive structure that will be the enabler to unlock these targets. And I think medical devices are going to need a similar thing because the autos have been in the country for a while. But the only reason it exists is that OEMs have directed tier ones to come here. They didn't want to see decide to start businesses here. And I think medical devices, it's the same thing, these companies, many of these, no, why would I start in your facility, there needs to be some kind of incentivization. And they will need to be some requirement in terms of local content. Otherwise, when we come out of COVID, why would you want to make a toy, you could import one from China at half the cost, you need to have these policy driving this localization, which is why, in other sectors, we touched them slightly like chemicals and whatever, they struggle with black supplier development because there is nothing mandated or incentivized forcing you to do it, you do it if you're passionate about it. There's nothing."

4.5 Economies of scale

The interviews with all candidates indicated that the manufacturing sectors involved in the production of ventilators can mass-produce ventilators and other medical equipment such as personal protective materials. As the participant from NACAAM indicated the automotive sector struggled with the low number of orders it received from the DTIC than a capacity shortage. For example, the participant from NAACAM stated that;

"So we've got the auto pays for 2000 units, we manage consecutive shifts to push out all 2000 units at one point, we didn't see any point in staggering the production of this, because remember, for the automotive guys, for us to start up align if there's not full capacity, it's highly inefficient, you know, so many of them by this point, we're probably in the latter stages of level four of lockdown. So during level four of lockdown, automotive companies were allowed to operate at 50% of the normal capacity. So our suppliers were effectively back at work at that point, but with only 50% of the staff. So we saw this as the opportunity to bring the other 50% back in the short term capacity to work on the ventilator thing. So but as I said to the challenges that ventilator volume was so small, it didn't make sense staggering. This production over multiple shifts. So many of the suppliers ran two or three shifts back to back

and pumped out all the components they needed for a ventilator and sent them all off to MCR at one point in time"

The participants from SARAO also alluded that capacity was not an issue but a market beyond COVID-19. Therefore capacity was not in question but the availability of market for future production.

5. Discussion

The purpose of this case study was to investigate the importance of state institutions, public organizations and the private sector reorienting their innovation and production efforts in times of crisis, the research also looked into aspects of the design, development, production and procurement of ventilators. This chapter presents the discussion of main findings as related to the literature on lateral migration, global value chain, public-private partnership and industrial policy. The chapter also centralized on the two hypotheses indicated out in the introduction section namely;

H1: The success of reorienting innovation and production efforts depends on strong a partnership between the state institutions, public organizations and the private sector.
H2: Industrial and innovative policies are the pillars for successful manufacturing.

While there may be several dimensions to looking into the NVP, for this research, we have looked at it through the lenses of (i) Public-private partnership; (ii) Lateral migration; (iii) Global value chain and (v) industrial policy. Each category is discussed in depth below. Thereafter the chapter concludes by providing recommendations and the shortcomings of the study.

5.1 Public-private partnership in the South African National Ventilator Program

As indicated in the literature review PPP differs from privatisation, outsourcing and collaborative government (Wang et al., 2018). And PPP is more about risk sharing, easing the process of knowledge transfer, easing bureaucratic hurdles, delivering timely projects, creating investment facilities and creating long-term markets (Tang et al., 2010). Except for long-term markets all these elements have exhibited in the project, thus the findings from the

NVP case study affirmed that public-private partnership is key for successful project execution.

The first main contribution that the state made was that the government-funded for the ventilators that were manufactured by CSIR and bought the ventilators that were produced by SAVE-P or NACAAM. That eased the burden of risk both from the private and the public sector. As one of the interviewees stated that "the government fully funded the project through the solidarity fund and also assisted us with product development with helped us spread the cost of development". Thus the statement clearly emphasised that the greater extent the partnership contributed to the success of the project and the presence of risk-sharing in the process.

Beyond risk sharing, public institutions like Sector Education and Training Authority (SETA), public universities and other private organisation volunteered to facilitate research and development programs focused on building and strengthening the manufacturing skills required for the production of ventilators. Thus knowledge and skills transfers were eased due to the partnership. As one of the participants indicated that of the many challenges they faced was finding the right partners in the short time they had but due to the extended network the Department of Trade and Industry (DTIC) had managed to find partners suitable for the project. She then highlighted that the most important ingredient to get done a lot of work in a short period is that, the right partners.

The second most challenging scenario that emerged in the project was getting regulatory approval. All participants alluded to the regulatory hurdles they faced in the completion stage of the ventilators. One participant stated "getting a licence was next to impossible". Nevertheless, they all believe that the only reason they managed to overcome the situation is that the state involvement in clearing bureaucracy.

However, the benefit of PPP in creating long-term market opportunity as discussed in the literature review was not present in the NVP. Although DTIC published guidelines for the manufacturing use of supply to avoid delays from bureaucracies the licences given was only for the ventilators to be used during the Covid-19 purposes. Thus the possibility of a future market is hindered unless there is a policy or licence change.

Nevertheless, the partnership has enabled the timely delivery of the ventilators. And the risk-sharing between the private and the public sector has enabled private sectors like NACAAM to embark on innovation and diversification without fear of financial loss. Nonetheless, South Africa is not the only country that has embarked on PPP to address medical equipment shortages, countries like United States, United Kingdom, France and others have done the same (Panzini and Gibney, 2020). Although South Africa succeeded in ventilator production through partnership and mechanisms the same couldn't be said about vaccine manufacturing rather there is a structural failure in that manner (Ho, 2021).

5.2 Technology and skills transfer from automotive, aerospace and other sectors into NVP

The lateral migration literature focuses on knowledge transfer from resource-based activities to knowledge-intensive activities. However, as mentioned in the literature review section this research extends the study by looking into knowledge and skills transfer from non-resource to knowledge and technology based sectors. And the presence of lateral migration is looked at through (i) whether the sectors were able to upgrade into advanced technical skills through research and development (R&D) for the NVP (ii) the contribution of foreign knowledge to the process of innovation (iii) the importance of systemic dynamics for knowledge intensification through linkages and interaction between firms, science institutes and universities and (v) the extent to industrial policies contribute to driving innovation for the success of lateral migration Lorentzen (2006).

The initial technologies used in the automotive and aerospace sectors weren’t backward at the start. However due to the nature of medical equipment’s which require extra careful attention that forced the sectors to adjust to the needs that arise. For example, a participant indicated that a brake callipers manufacturer had to clean out the entire logistics warehouse and everything that was in the warehouse was removed to epoxy the floors, to put dust control air system and to decontaminate the entrances. That is done so that it would be suitable for the assembly of the ventilators. The other necessary upgrade was done through R&D and knowledge sharing. As one participant mentioned that the diving component manufacturers use the knowledge of how to provide oxygen to divers, deep-sea divers not only that but also they came up with the hood that could be connected to the ventilators and worn over. The

R&D was done throughout the project in partnership with SETA, universities and other private sectors. Thus the participant sectors were able to advance technologies through R&D.

When it comes to foreign technology the most notable contribution foreign technology had in the NVP is that through the design used by NACAAM. The finding clarifies that the design used by SAVE-P was a 1980s design that was created by a British company and that was out a patent. Besides that, there was some form of international consultation as the crisis was global and the majority of advanced countries were trying to produce ventilators but not a specific foreign technology that could be identified was used in the project (Panzini and Gibney, 2020).

However, the linkages and interaction between local firms, science institutes and universities for knowledge intensification were notable. For example, one participant explained how they approached other firms to work with. She stated that "we would go out into the automotive sector and said to a company which makes puncher door panel for Ford, then try to figure out with their existing tooling, the existing raw materials that they have, ask if they can sort of reconfiguring that tooling to be able to manufacture this medical device component". Her statement and the expression from other participants confirm that components used for the ventilators were made by the different participant and the knowledge sharing between companies go to the extent where even tyre making experts involved in designing the rubbers used in the ventilator.

On the other end, the role of industrial policy was minimal in the project. Although there was no specific policy crafted for NVP. As one participant puts it, the existing industrial policy that helps the automotive sector ease the industrial process especially when it comes to accessing local raw materials was hand for the NVP project. Although the project was successful for the time being, the lack of government policy or intervention that seeks to attract investment and resources for the long-term growth potential, which would not take place in the market equilibrium state hinder the prospect of medical equipment manufacturers in South Africa.

5.3 The weakness of the Global Value Chain exposed by NVP

The very reason for the initiative of the NVP is the unavailability of ventilators to be imported as every country prioritises its citizens and GVC was interrupted (Fourtunato, 2020). Furthermore, some countries banned export and many closed their borders and protectionism was the dominant strategy seen by the majority of the developed countries (Fourtunato, 2020). Thus the NVP was created out of necessity. One of the factors that showed the weakness of the chain was that in the face of such a crisis countries that have no manufacturing capabilities are in danger (Fourtunato, 2020).

Luckily the South African manufacturers had capabilities at hand except for the minor skills gap. For example, one participant indicated that the face shield that had to be attached to the ventilator had to completely cover the face in a way that no air passes through but finding the technical capability to manufacture such a shield to the quality needed was impossible due to the short period available. Thus that component needed to be imported but due to the GVCs disruption accessing that component was close to impossible. But with the state directly involving in the matter, it was eventually solved.

5.4 Industrial policy

The findings indicated that there wasn't specific industrial policy that was crafted for NVP. Although not termed as industrial policy many of the charchterstic of industrial policies that were defined in the literature reviw section were exhibited in NVP. The main shortcoming is that the contribution of these industrial policies are not guaranteed to be in the long-term unless specific industrial policy is crafted.

The reason for the argu,ment that the characterstics of industrial poloicy were exhibited are; as stated by Oqubay (2015) the main aim of industrial policy is to build cababilities of domestic firms and the finding shows that the state strongly contributed 9in domestic capability building through providing finces and R&D for NVP. The other role of industrial policy seen in NVP is that assurance for innovation. Shaouha (2020) argued that the role of industrial policy to assure industries to innovate. Thus the finding confiremed that the stated assured industries to innovate for the manufacturing of ventilators by providing R&D, easing the regulatory hurdles and furthermore by purchasing the ventilators for public hospitals.

Although the economic rational for industrial policy is increased per capita income growth, increased labour productivity, faster capital accumulation, spill over effect and rapid economic growth, these all cannot be achieved with a six months once-off project (Szirmai, 2012). If South Africa has to benefit from medical equipment manufacturing, the state needs to create a long-term specific industrial policy for the medical equipment manufactruring sector.

5.5 The hypothesis in light of the findings

The role of Public-private partnership and industrial policy in the NVP was the main focus of the research aimed to examine. And the first hypothesis presented forward was the overall success of the project depends on the strong PPP that was exhibited in the project. The findings from the study strongly support this hypothesis. One participant plainly stated that if it was a plain government-owned project the chance of the project succeeding was close to none. Not only that but the coordination, risk sharing, knowledge sharing and investment that was created from both the public and private sector made that project successful.

However, the evidence found from the study undertaken does not strongly support the second hypothesis proposed. The second hypothesis stated that industrial and innovative policies are the pillars for successful manufacturing. Although the contribution of industrial policies for successfully attracting investment and resources in the productive sectors with high economic growth potential, which would not take place in the market equilibrium state was stated in the literature, there was no specific policy crafted for NVP there was project. Nevertheless, there was an existing industrial for the automotive sector was used for the procurement process. Thus there is no sound ground to conclude that industrial policy was at the pillar of the project.

5.6 Recommendations

The evidence found from the study has indicated that the expected ventilators were completed in the time frame. However further production isn't possible as the licence to use the ventilators is limited to the Covid-19 health crisis. The other shortcoming is that the lack

of a testing facility and the lack of an existing certification process for medical equipment's produced locally. In addition to that, there is no clear policy that the state created to make the diversification carried on in the economy in the longer term.

Therefore the state has a testing facility for locally manufactured medical equipment's. And the approval and licensing process have to be established locally than going elsewhere to certify for the products manufacturing locally. Moreover, if the country has to benefit from continued medical equipment manufacturing there must be incentives and clear government policies to encourage diversification and innovation.

5.7 Shortcomings of the study

Initially, the study aimed to interview participants from the state institutions and the employees involved in the project alongside the project leaders and the lead Engineer. However due to the unavailability of the state representative and employees combined with the limited interaction due to Covid-19, getting access to the state representative and employees impossible. Thus the perspective of the public sector and employees is not included in the study.

Furthermore understanding the reason why there was no industrial policy and how employees adopted the unprecedented working environment change was not explored in the study. Therefore future studies may investigate the reason for the lack of industrial policy by conducting interviews with public sectors representatives and the process of worker adaption to unprecedented change by engaging with employees.

6. Conclusions

Overall, the research indicated that the success of the national ventilator project was embedded in the project participants' ability to reengineering and retooling their local manufacturing capabilities. Moreover, the findings also exposed that there is actual capability, production capability, investment capability and economies of scale in the South African manufacturing sector to go beyond ventilators and to produce other medical devices. The project managed to manufacture the required (set by the DTIC) amount of ventilators on

time. However, the lack of clear industrial policy to support the continuation of this diversification, the hurdle to get regulatory approval, and the lack of testing facilities for medical equipment might hinder the feasibility of future medical equipment manufacturing. In addition to that, the ventilators are only approved to be used during the Covid-19 health crisis which jeopardises the longevity of the project.

Nevertheless, the contribution of public-private partnership and knowledge transfers within industries are the most important contributors to the favourable outcome of NVP. Although the regular requirement process was edgy, the government intervened to ease the process for the time being. The important factor was the involvement of research and development institution and other entities to transfer skills needed and to share knowledge.

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